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Quarterly Progress Report

Division 7

Engineering

15 March 1964

Prepared under Electronic Systems Division Contract AF 19(628)-500 by

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts

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INTRODUCTION

The Engineering Division is responsible for mechanical, construction and control engineering for all Laboratory programs. Some of the principal projects worked on during the three-month period from 1 December 1963 to 29 February 1964 are detailed in this report.

The major effort under the General Research program has continued to be on the Haystack Hill antenna system and facility. Initial assembly of the antenna is nearing completion, and design of the RF equipment boxes, test docks, and system interconnections is well advanced.

In the Re-entry Technology program, mechanical design of the instrumentation for the PRESS KC-135 aircraft has been essentially completed. Modifications of the 48-inch telescope at Wallops Island, Virginia and of the AMRAD radar at White Sands Missile Range have been initiated.

Design of the Lincoln Experimental Terminal for the Space Communications program has continued. In addition, a considerably increased effort is being expended on the design and development of a communications research satellite.

The Apollo program support has involved the design of equipment for lunar reflectivity studies and for an optical radar.

J. F. Hutzenlaub
Division Head

15 March 1964

This technical documentary report is approved for distribution.

Franklin C. Hudson

Franklin C. Hudson, Deputy Chief
Air Force Lincoln Laboratory Office

TABLE OF CONTENTS

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MECHANICAL ENGINEERING
GROUP 71

I. GENERAL

The Mechanical Engineering Group participates in the engineering and design efforts for all Laboratory programs. At present, the major tasks are for the Haystack project, and the Reentry Physics, PRESS, and Space Communications programs. On-site mechanical engineering support and accompanying design work continue for the Radar Discrimination Technology program.

The engineering and design tasks for the Haystack project are reported in the Group 76 section of this quarterly progress report.

II. LABORATORY SERVICES

A. Cryogenic Equipment Laboratory

During this reporting period, evaluation of closed-cycle refrigerators for use with operational systems continued. The three-gas refrigeration system which utilizes nitrogen, hydrogen, and helium has been cooled to 4.2°K successfully for the first time. Additional cooling tests are to start in the near future.

The Arthur D. Little, Inc., Cryodyne has failed to reach the guaranteed number of continuous operating hours and has been returned to the company for engineering evaluation.

A third unit, the Cryogem, manufactured by North American Philips Company, Inc., has undergone refurbishing after 250 operating hours. This unit has a predicted life of only 250 hours and, therefore, does not appear to be feasible for installations which require long-term operation.

III. GENERAL RESEARCH

A. Millstone Hill L-Band Antenna System

The Millstone Hill L-band antenna system is nearing operational status, with minor modifications and improvements being made as necessary.

Lincoln Laboratory Manual, LM-53, "Millstone L-Band Monopulse Radar Antenna System Preventive and Corrective Maintenance Procedures" (December 1963) has been prepared for publication. The manual, which contains three sections, provides operating personnel with information for maintaining the Millstone L-band monopulse system at a high level of performance. The first section describes those portions of the system which have been upgraded to meet L-band requirements. The second and third sections provide service and maintenance instructions for the new or modified portions of the system.

This manual supplements the information in Lincoln Laboratory Manual, LM-40, "Instruction Manual for Millstone Hill Type Antenna System" (August 1959).

B. Structures Research and Evaluation

Work has continued on the paraboloidal shell analysis and on the development of a computer program for framed structures.

1. Paraboloidal Shell Analysis

Part IV of Group Report 71G-1, "Distortion and Stresses of Paraboloidal Surface Structures," is complete and ready for publication. Groundwork for the study of the behavior of shells under edge loads and distortions is under way.

2. Improvement and Development of Computer Programs to Analyze Structures

This effort, approximately 75 percent complete, has involved the following:

(a) "Ill-conditioned" matrices can now be successfully detected by the STAIR computer program. Such matrices, if only moderately ill-conditioned, can be corrected by a double-precision inversion method rather than by the standard single-precision method. If a matrix is badly ill-conditioned, a conjugate gradient (iteration) method is used to obtain the inverse. Each of these methods requires successively more computer time than the previous method. At present, the range of ill-conditioning governing the use of each method has been arbitrarily set. More realistic values, if required, will come from experience. The two new methods of inversion are now in a final debugging stage.

(b) The IBM frame analysis (FRAN) check step has been completed and is working successfully. It has already detected analysis problems where none were thought to exist.

(c) The derivation of a new lattice analogy for shells has been developed. A computer program is now being written to set up and solve these matrices. The resulting deflections will be checked against known solutions.

IV. RE-ENTRY PHYSICS

A. 48-Inch Spectrometric Telescope

Modifications to improve and augment the capability of this telescope are presently being undertaken.

1. Tracker Redesign

A new tracking head is being designed which will replace the present 48-inch tracking head (fine tracker) and completely eliminate the use of the 12-inch tracking telescope (coarse tracker).

Located behind the primary mirror, the new tracker will intercept the light coming through the 11-inch hole in the primary mirror by a thin membrane or pellicle. This pellicle allows 90 percent of the light to pass through to the spectrograph entrance slit which is located at the prime focus of the telescope. The other 10 percent of light is reflected 90° to a composite mirror which rotates at 3600 rpm. The mirror consists of a field lens, a neutral density wedge combination in the center, and a concentric spherical mirror, half of which has silvered blades deposited on it. If the telescope is almost on target, the light will fall upon the center portion of the mirror, be modulated by an external chopper, and then picked up by a photomultiplier tube. The neutral density wedge relates the position of the target to the center of the telescope, which then acts as the fine tracker.

If the light is outside of the field lens area and falls upon the spherical mirror, it is chopped and reflected by the silvered blades to another photomultiplier. This portion of the optical system, termed the coarse tracker, directs the servo system to reposition the secondary mirror until the light falls into the area of the fine tracker.

2. Secondary Mirror Actuator Redesign

A new design has been undertaken to improve the performance and reliability of the secondary mirror actuators. Improved performance was required because of the proposed installation of high resolution linear encoders. The following features will be incorporated into the linear actuators:

Snubbers at the end of the ram travel for controlled stroke deceleration

A mechanical locking pin (hydraulically or manually operated) to hold the actuator in the null position for calibration

A valve to permit flushing of the external hydraulic system without contaminating the actuator filters

A transducer internally mounted in the linear actuator

Dovetail slide mountings for the actuators to facilitate optical focus adjustment

The mechanical design studies for the preceding have been completed and are being released for vendor quotations.

3. Encoder Installation

Sixteen-digit angular Baldwin encoders are to be incorporated in both the elevation and azimuth axes of the telescope mount. The design of the mounting for the elevation encoder has been completed and released for manufacture. The mounting for the azimuth encoder is still being studied.

4. Slip-Ring Assembly

The replacement of the present 100-slip-ring assembly by a 145-slip-ring assembly is being considered. Design studies are being performed to configurate a mounting structure for the new slip-ring assembly and for the azimuth encoder assembly.

B. Trailblazer II Optical Experiment

A prototype assembly of the optical payload is currently being made, and several of the subsystems have been tested. The optical system has successfully withstood prototype level tests for vibration, shock, and g loads. A partial assembly of the unit, exclusive of the optical system and photomultiplier tubes and their electronics, is currently being tested to qualify the drum recorder and commutator.

Design of the optical payload is complete except for minor modifications to accommodate the electronic packaging. Fabrication of many of the components has begun and the remainder are now being released for manufacture.

V. PRESS PROGRAM

A. KC-135 Airborne Instrumentation

Since the KC-135 aircraft departed for Phase II down-range operations in late December 1963, design and construction have been continuing on the Phase III complex. Return of the aircraft for Phase III structural modifications is scheduled for late April; this will permit installation of equipment to begin in the second half of June.

GROUP 71

1. General Arrangement – Phase III

Installation plans were approved by Group 32 (Pacific Range Measurements), and Group 71 is proceeding with the detail design of the installation.

2. Control Systems

The instrument mount and instrument control systems have been agreed upon and detail circuit and console designs are in progress. Breadboard tests of the elevation and deflection servo amplifiers have been completed and pilot models are being constructed in the Electronics Shop. All translation servo amplifiers will be delivered by mid-March. The vendor is presently performing acceptance tests of the command servo.

3. Instrument Mounts

Design of the aft equipment mount has been completed and fabrication of most of the components is in progress. The gimbal assemblies have been completed and, in some cases, the actual instruments have been installed to establish static balance requirements.

The six main frames have been machined and are undergoing inspection, as are the fore and aft base pad assemblies. The base has been machine finished and is due from the vendor. Both the vertical and horizontal drive assemblies are being fabricated.

General Electric's Flight Test Operations in Schenectady, New York, is completing the design of the aircraft interface, which consists of a steel-beam torque-box structure that attaches to the aircraft at two deep bulkheads (stations 820 and 960). Necessary stiffening is being incorporated into these bulkheads, and a shear plate to absorb forward crash loading will be installed extending aft from station 960.

The design of the forward mount is nearing completion contingent upon a suitable interface arrangement with the aircraft structure. For ease of access to the pilot's compartment, the stowed position of this unit is now at the aft end of its travel, toward the Skyscraper unit. General Electric has designed a new cargo door actuator to eliminate interference with the motion of the long focal length camera assembly.

A portion of the aft mount interface is being fabricated to permit preliminary assembly of the complete mount in the mock-up room at the Laboratory.

4. Material Handling Equipment

Before and after each mission of the aircraft, all optical units must be calibrated under field conditions at Hickam Air Force Base, Hawaii. In order to position the special collimators on the outside of the aircraft windows, an aerial lift equipped with a personnel basket and davit hoist, and mounted on a transport vehicle will be used. From the basket, and by means of remote controls, the operator will first remove the dust covers from the windows and then attach mounting brackets to the window frames prior to lifting the collimators from the ground and placing each one in its mounting cradle at the proper position for calibration.

In addition, at both the Hickam and Wake Island facilities, portable roll-around scaffolding will be provided to permit personnel access to the window area for dust cover removal, window washing, bracket attachment, and collimator service.

Procurement specifications are now being prepared for both the aerial lift transport and the scaffolding.

B. Collimator for the Multi-Element Total Event Spectrometer (METES)

Rearrangement of several of the optical elements in the collimator has resulted in a configuration which will be easier to handle and store. Design is 80 percent complete and it is anticipated that the design will be released for manufacture in March.

The collimator will be mounted on the external side of the KC-135 aircraft window in front of each of the METES spectrometers and will be used to calibrate the instruments before and after each mission.

C. Laboratory Collimator

The expanded Laboratory model of the METES calibrator is now being assembled and should be ready for use early in March.

D. Recording Optical Tracking Instrument (ROTI)

Field reports on the performance of this unit, located on the island of Roi-Namur, indicated the necessity for a general mechanical inspection, with particular attention to the following:

- Modification of the elevation gear drive system to reduce backlash and improve the gear and bearing lubrication system
- Adjustment of the azimuth gear drive system to reduce backlash
- Determination of the imbalance about the elevation axis to be followed by the necessary action to minimize such imbalance
- Measurement of the flatness and level of the azimuth bearing

An engineering team from Group 71 has been dispatched to Roi-Namur to accomplish the preceding.

VI. SPACE COMMUNICATIONS

A. Lincoln Experimental Terminal (LET)

Design of the 15-foot Lincoln Experimental Terminal is proceeding on schedule. Final design of the antenna itself has been completed and an order has been placed with the Advanced Structures Division of the Telecomputing Corporation.

The RF portion of the antenna system is proceeding with the release for manufacture of full-size feed components as well as $\frac{1}{3}$-scale components for model studies of primary patterns and possible configurations of tracking feeds. Design studies are being initiated which will determine the location of the many RF components as well as the cooling and monitoring equipment associated with these components.

The azimuth bearing has been ordered from Kaydon Engineering Corporation of Muskegon, Michigan, and the basic electronics van has been ordered from Fruehauf Trailer Company, Waltham, Massachusetts.

Quotations have been received and proposals are now being evaluated for gas-turbine alternators, the electronic power supply, and the slip-ring assembly.

B. Communications Research Satellite

Reappraisal of the requirements for carrying this communications satellite on a specific vehicle resulted in some configuration changes. The satellite's maximum weight was changed from 25 to 45 pounds to permit flexibility and to provide the capability for carrying additional experiments not now defined. An increase in satellite size to 24 inches across flat sides allowed space around the solar panel edges for additional area to radiate heat. This also provided edge mating to adjacent panels, permitting heat transfer to these panels by conduction. The TE-375 Thiokol solid propellant rocket motor has been selected to inject the satellite into the correct orbit.

1. Satellite Structural Design

Structural design studies, which consider weight reduction, materials, fabrication, hold-down method, and a new load environment, have been made for the 25-pound satellite frame. The original frame, as built, weighed 4 pounds. The $\frac{3}{8}$-inch-diameter tubing used was 6061-T6 alloy with wall thicknesses varying from 0.018 to 0.065 inch. Further design effort reduced the frame weight to $2\frac{1}{3}$ pounds.

The material for the aluminum investment cast hubs for the $\frac{3}{8}$-inch-diameter tubular structural frame of the satellite has been changed from Tenzaloy to Precedent 71-A heat treated to T6. This increases the yield strength to 40,000 psi compared to 28,000 psi for Tenzaloy. The hubs have been redesigned to reduce weight and to accommodate the new solar panel design.

A parallel program of an epoxy-bonded frame has begun with the help of the Materials Processing Section of Group 73. A selective study was made of various adhesives.

Epoxy tensile shear tests indicated that the Minnesota Mining and Manufacturing Company EC-2086 had the highest strength for this application, and further tests were conducted on this adhesive. Sand-blasted tubing inserted into test sockets and bonded with EC-2086 to simulate the actual frame joints was tested. The results of these tests indicate that the epoxy joint shows promise. Additional structural tests are planned.

Tooling is currently being designed to build a complete satellite frame using EC-2086 epoxy at the joints. An epoxy-joined frame would allow the use of the higher strength 7075-T6 aluminum tubing with a weight saving of approximately 0.15 pound. Another advantage in the epoxy-joined frame over the dip-brazed frame is that there is less distortion of the frame during the joining process. The 7075-T6 tubing cannot be used in a dip-brazed frame since the brazing temperature is above the melting temperature of this aluminum alloy.

Gamma radiation exposure tests are scheduled for EC-2086 epoxy joints to determine what effect, if any, the radiation will have on the mechanical and physical properties of the epoxy adhesive.

Efforts are now aimed at a redesign of the structure to support a total weight of 45 pounds using an internal hold-down device.

2. Solar Panel Design

The solar panel substrates have been enlarged so that they are $9\frac{1}{2}$ inches square. Another edge member on all four sides will enable the panels to be fastened to each other and to the triangular members, in addition to being fastened to the frame. These changes will improve the thermal balance of the satellite by increasing the radiating area around the panels and increasing the conduction between panels.

The substrates being considered are aluminum honeycomb sandwich panels $\frac{1}{8}$ inch thick with 0.005-inch-thick skins and extruded aluminum edge members.

3. X-Band Horn Antennas and RF Switches

The total number of X-band communication antenna horns has been reduced from 32 to 8 – one horn in each triangular corner panel. The angular orientation of each horn is such that complete and symmetrical coverage is still obtained in all directions. The shape of the antenna has been changed from a circular-conical fin-loaded horn to a straight cylindrical horn.

The solid state X-band switching system used to switch the antenna horns in proper sequence has been reduced from eleven switches to three – two single-pole 4-throw switches and one single-pole 2-throw switch. A lightweight, dip-brazed aluminum, single-pole, 4-throw switch has been constructed and has been successfully checked out electrically by Group 61 (R. F. Components). An aluminum, single-pole, 2-throw switch is currently being designed.

4. Spin Table, Support and Ejection Mechanism

A prototype design of a mechanically actuated spin table has been completed. The spin table is powered by a cluster of negator spring motors, symmetrically located about a central spindle. The payload is connected to the spin table through a unidirectional clutch consisting of mating conical surfaces and a bayonet type lock. The inner cone is attached to the spin table and the outer cone to the payload. When the spin rate is reached, the spin table is stopped and the clutch automatically separates. A conical compression spring guided by a parallel mechanism then separates the payload at the desired push-off velocity. The parallel mechanism, called "Sarruts Mechanism," eliminates tipping of the payload during separation.

The satellite system is locked on the spin table structure through a marmon clamp. This clamp is released by two explosive bolts, starting the spin and ejection sequence automatically.

5. Satellite Support and Ejection

The satellite system consists of the satellite, a de-spin mechanism, a Thiokol TE-375 spherical rocket motor, and associated support structures. After spin-up and ejection, the rocket motor is fired, the Yo-yo de-spin mechanism is deployed, and finally the satellite is separated.

Many techniques for supporting the satellite have been investigated. The problem is complicated by the excessive area covered by the solar panels and the need to limit the protuberance of the supporting mechanism so that it does not shadow the solar panels. The most feasible technique to date utilizes four ball collets, one at each of the bottom corners of the satellite frame. The ball/collet connection carries tension, compression, and shear loads.

6. Shock and Vibration Testing

During the past quarter, the 25-pound dummy satellite was tested under sine-wave vibration, random vibration, and shock. The satellite was completely paneled with solid aluminum panels to simulate the solar panels, and two equipment shelves were attached internally to simulate a double instrument package.

The maximum observed stress during sine-wave and random vibration tests was 9250 psi at 2600 cps on a horizontal member (in the plane of the lower shelf) at the outer periphery. This took place during horizontal vibration of the satellite.

Three accelerometers at various internal and external locations continuously monitored g loads and resonance frequencies during these sine-wave and random sweeps. The highest magnification recorded was 73 times the input at the top outside corner of the satellite; this was recorded under a 440-cps vertical input.

For the vertical shock tests, the highest stress recorded was 1850 psi (compression), and the largest shock magnification was 1.8 at the simulated instrument shelf center.

During the horizontal shock tests, the highest stress recorded was 12,200 psi (compression), and the largest shock magnification was 2.0 at the outer top corner of the satellite.

At the completion of the above tests, visual inspection of the satellite revealed no damage.

VII. RADAR DISCRIMINATION TECHNOLOGY

A. AMRAD

The AMRAD site at the White Sands Ballistic Missile Range, New Mexico, was turned over to Lincoln Laboratory for operation on 20 December 1963. Since that time, the following mechanical programs have been undertaken.

1. Tower Rework

Reworking of the internal tower access on the first three levels, access to the receiver room and top deck by means of external ladders, and improvement of safety guard rails at the top of the tower have been found necessary. The design portion of the effort was done by Group 75.

2. Lubrication

On-site problems with the antenna drive system lubrication required a change in the type of lubricant being used. Serious difficulties were encountered while using Pen-O-Led EP-1 lubricant, manufactured by Humble Oil Company. Water entering the oil, either through leakage from the clutch cooling system or from rain water running off the structure, united with lead naphthenate in the oil and formed a sludge which clogged filters and reduced lubricant flow. On recommendation of Humble Oil Company, a changeover is being made to gear oil GP-80. Preparations are currently being made to drain the EP-1, flush the system with varsol and light oil, put in new filters, and refill with gear oil GP-80.

3. Receiver Alignment

Since the present method of aligning the receivers was judged inadequate, a new alignment tool has been designed. It is a four-way power divider, in WR 650 waveguide, consisting of one H-plane folded hybrid tee, two E-plane folded hybrid tees, special panty adapters, and four transitions from rectangular to circular guide. This tool will be bolted onto the antenna in place of the horns.

Work has started on a scale (1:6.55) model of the primary and secondary reflectors. This model, with an appropriate mounting structure, will be attached to a mount at the Laboratory's antenna range. The purpose of the model is to test new feed-horn designs that will improve system performance.

4. Azimuth Bearing Releveling

This operation is necessary to correct a level error of 55 seconds in the azimuth bearing plane. This involves jacking up the lower pedestal and shimming with graduated shims. The complete procedure has been set forth in a Raytheon Company memorandum to the AMRAD site manager. Shims, level points, and jacks are being prepared to undertake this operation.

5. Upgraded AMRAD Driver

The console frame was delivered during this quarter, and installation of circuitry, power supplies, related mechanical subassemblies, and cabling in the high voltage area is nearing completion. Electrical and mechanical design, fabrication, and installation of the ground plane and "crow bar" system will be accomplished after delivery of the 10-μf, 30-kv storage capacitor. Design work on the control chassis and pulse generator panel, and alterations to the Vac Ion pump supply and the 30-kv power supply for installation in the control area of the frame are also under way.

VIII. APOLLO

A. Lunar Reflectivity Studies

Lunar reflectivity studies will be conducted at Flagstaff, Arizona by Group 28 (Control Research), with an optical instrument now being designed, built, and assembled.

The complete assembly utilizes an existing sidereal mount which is being modified, an 18-inch Cassegrainian main telescope, an 8-inch Cassegrainian finder telescope attached to a TV camera, and three instrument packages.

The three interchangeable instrument packages will be mounted at the prime focus of the 18-inch Cassegrainian system. The first package contains a high precision image dissector; the second, an eyepiece for viewing the prime focus; and the third, the means for photographing the prime focus. The design is 80 percent complete and sections of the instrument have been released for manufacture.

B. Optical Radar for Near-Infrared Region

Design of a Cassegrainian telescope has been completed and vendor quotations have been requested. It is anticipated that this contract will be awarded early in March.

The telescope has a 10-inch-diameter primary mirror with a focal length of 20 inches and an 8.83-inch effective aperture. The telescope is to be the receiving optics for an optical radar operating in the near-infrared region and will contain mounting provisions for a transmitter. The detector is mounted in a standard holder incorporating an optical filter and will have scanning capability. The radar is to be used for laboratory and field testing at several locations. This telescope will resolve objects separated by ten seconds of arc, at any angle, in a field of view of 2°.

CONSTRUCTION ENGINEERING
GROUP 75

I. GENERAL

Construction programs during this reporting period have proceeded with a minimum loss of time despite adverse winter conditions.

Construction of the radar transmitter research facility, the first stage of the Millstone storage building, and Phase 1 of the new boiler room at the radar site at Millstone Hill should be completed early in the next quarter. The radome heating system at the Millstone Communications Site was redesigned, procured and placed in operation early in this quarter.

Consultation on the expansion of the AMRAD facility at White Sands, New Mexico, is continuing. Design of the antenna access has been completed and construction work should be finished by late spring.

II. RADOME HEATING SYSTEM – MILLSTONE COMMUNICATIONS SITE

A. General

A heating and snow melting system for the 90-foot inflated radome has proved to be necessary. Any attempt to operate this antenna system through a wet layer of snow would reduce the efficiency of transmission to a point that any data obtained would be of little value to the program. In addition, the proximity of the antenna system to the operations building and the main access roadway has caused considerable concern for the protection of personnel and property from the dangers of sliding snow and ice.

B. Design Criteria

It was required that the heating system have the capability of melting snow as it falls on the surface of the radome.

From records kept at the Millstone Hill Radar Observatory, it was determined that rates of snowfall in excess of 3 inches per hour were not unusual for the area. The average temperature during a period of heavy snow fall is approximately 20°F. Thus, a snowfall rate of $2\frac{1}{2}$ inches per hour at a temperature of 20°F with a 15-mph wind was established as a reasonable basis for design.

The space to be heated consists of a 90-foot-diameter, inflated, vinyl-coated, nylon radome, with a thickness of 35 mils and a 64- by 31-foot reinforced concrete support structure.

It was determined that an inside temperature of 75°F was required to maintain a temperature of 34°F on the outer surface of the radome. It was assumed that only one-half of the radome surface would have snow cover. It was further determined that, under the above design conditions, 250 Btu/hr/ft^2 of heat transfer would be required. Thus, the total heat required for snow melting was determined to be 3,699,000 Btu/hr.

C. Equipment

Since the space under the radome was not satisfactory for the installation of a heating plant, a minimum-cost metal building was erected to house the pumps and boiler plant.

The heating system consists of one 125-hp, packaged hot water boiler with a rated output of 4,184,400 Btu/hr. Because continuous service of plant maintenance personnel was not available at the site, No. 2 oil was selected as fuel for the system. Since the system was installed during severe winter conditions, the oil storage tanks were placed above grade, thus saving considerable time and unnecessary construction effort.

Hot water is circulated with a 3-hp circulating pump that has a capacity of 200 gph at a 35-foot head. Heat flow inside the radome is achieved with two 2,000,000 Btu/hr unit heaters. The heater blowers are powered with $7\frac{1}{2}$-hp electric motors. The heaters are controlled by individual thermostats that actuate pneumatically operated valves.

D. Operation

Because there is no other source of heat in the boiler room or radome, the system is designed to operate so that the boiler and circulating pump run continuously during the heating season to prevent freezing of the hot water heating pipes and boiler. In the event of a lengthly breakdown during cold weather, the system must be drained to prevent freezing.

Operating thermostats in the radome will modulate a three-way valve on each heater unit to maintain a set temperature in the radome. When the temperature set on the thermostat is reached, water will circulate through the bypass on the three-way valves at the units to obtain constant water circulation and prevent the pipes from freezing. The fan motors on the heating units will operate continuously and will start up automatically after any control has shut them down, including loss of power. In such an event, the fans will operate automatically from emergency power. Freeze protection thermostats are installed in the heating units to turn off the fan motors when the radome temperature drops to 35°F. A pressure troll is installed in the radome to shut down the fan motors if the radome pressure reduces to 6 inches of water. In the event of control air pressure failure, the three-way valves will go to a closed position and the water will bypass the heating coils.

The heating thermostats will be reset manually from the normal operating temperature of approximately 60°F to a minimum of 75°F for snow melting. Two weighted relief dampers are installed and arranged to open when the pressure within the radome exceeds 6 inches of water.

III. ANTENNA ACCESS – AMRAD RADAR, WHITE SANDS

Recently, the 60-foot antenna system was placed in operation. Experience gained during the installation of equipment in the tower indicated that the access to the antenna system was unsafe and inadequate.

Since operational equipment had already been installed, design of a new system was more difficult than usual. Since there is a potential fire hazard due to the large quantities of oil used in the antenna drive system, two exits from the top of the tower were provided.

CONTROL SYSTEMS
GROUP 76

I. OBJECTIVES

Group 76 is responsible for the design and development of control systems for various Laboratory programs. The equipment consists primarily of automatic controls involving servomechanisms and computers.

II. MILLSTONE RADAR

Calibration of the reworked Millstone antenna mount has been in process during this reporting period. Results to date indicate that the azimuth plane of rotation is inclined 0.4 mrad with respect to the horizontal, as compared to 0.7-mrad inclination for the original mount. Additional tests will be made to correlate the inclinations measured with those produced by solar heating on the tower.

Preliminary tests indicate that the radar azimuth and elevation transmitters provide accurate readout of pointing angles to within 0.4 mrad. Further investigation of readout accuracy is necessary to eliminate wind effects noted during the calibration.

III. PROJECT WEST FORD

The analog orbit computer was installed at the Millstone West Ford site. Various modifications to increase the versatility of the computer have been suggested. These include provisions for great circle pointing, correction for the angle between the local vertical and the radius from center of the earth, and addition of a mean anomaly scan capability. These changes will be incorporated as the necessary equipment becomes available.

In cooperation with Group 62 (Surface Techniques and Equipment), considerable effort was devoted to reconciling solutions obtained by the IBM 7094 computer using the analog equations with solutions obtained by the same computer using the regular orbit program for calculating West Ford pointing angles. It was demonstrated that the two methods of solution are almost identical, but that different parameters of the earth's surface appear to be used. It is expected that differences in the results obtained by the two programs will be resolved in the near future.

Preliminary analysis of the pointing problems of the proposed Lincoln Experimental Terminal was completed. Drive motors and power amplifiers were tentatively selected, and a modified orbit computer proposal is being prepared.

IV. AMRAD

Discussions were held with the contractor and Group 45 (Range Measurements) personnel on final acceptance of the main servo system of the AMRAD radar at White Sands, New Mexico. It was decided to accept the contractor's description of system operation, although determination of actual system conformance to specifications must await the availability of a suitable target.

Preliminary design work was completed on the stabilization networks necessary for satisfactory pointing performance of the AMRAD antenna in its remote digital slaving mode. The limited data transmission rate and finite angular quantization found in the digital mode require stabilization techniques differing from those presently used for analog pointing inputs.

A Mark 51 Gun Director will be installed at the White Sands Missile Range to improve AMRAD acquisition capabilities. The position repeaters associated with the director were modified to provide one- and eleven-speed pointing information for AMRAD slaving. Remote indication of the AMRAD acquisition radar (AGAVE) pointing angles will be provided by installation of digital shaft encoders on the existing antenna position repeater unit.

V. APOLLO

An existing equatorial mount was modified to provide powered rate control of the antenna axes. This mount, which will carry a telescope for lunar reflectivity studies, was furnished originally with a synchronous motor drive in its hour-angle axis and a manual drive in its declination axis. The drives were redesigned to provide variable-speed closed-loop operation in each axis. Clutches were installed to provide the wide dynamic range necessary for tracking and slewing operations. Controls to produce independent slew, position correction, and rate correction inputs were provided.

VI. HAYSTACK HILL EXPERIMENTAL FACILITY

A. Lincoln Laboratory Activity

1. Antenna Equipment Boxes

a. Radar RF Box

RF Plumbing and Electronics:– The design of the transmitting waveguide plumbing was completed and all parts, except the new horn, have been released for manufacture. A layout of the arithmetic network has begun.

The layout of the 7750-Mcps transmitter is 90 percent complete. Work on the high voltage compartment and a reliable arc detector is continuing.

For waveguides handling high powers, it has been decided to use stainless steel flanges wherever possible. Solders now used for attaching these flanges to waveguides are inadequate, and an investigation has been started to find an appropriate solder. An annealed copper gasket, which is used once and thrown away, is being tested for use in flange-joint sealing as a possible replacement for the "Parker seal" type gasket.

Cryogenics for Low Noise Receivers:– Delivery of the closed-cycle refrigerator supplied by Air Products & Chemicals, Inc., has been delayed. However, the unit has been completed and is undergoing shakedown tests with a dummy parametric amplifier supplied by Lincoln Laboratory. Final acceptance tests for the unit are scheduled for the week of 24 February 1964. The unit is scheduled to arrive at Lincoln Laboratory during the early part of March.

The backup program of batch-type dewars for the closed-cycle system has progressed to where two nitrogen dewars and two helium dewars have been tested at the Laboratory with the following results: The nitrogen dewars have loss rates of 0.099 and 0.112 liter per hour, whereas the same dewars for helium have rates of 0.365 and 0.288 liter per hour. The helium dewars have a poor vacuum but, when cryopumped, demonstrate loss rates of 0.176 and 0.298 liter per hour. A spare dewar is expected early in March.

Structural Design:— The mechanical design of the radar box is approximately 70 percent complete. Fabrication is approximately 40 percent complete. The electronic equipment racks and honeycomb floor panels have been received. The floor panels are presently being installed. Design areas under consideration include cable distribution, air conditioner ducting, and major component mounting and support. The major fabrication effort, however, is being expended on the radiometer RF box at the present time.

b. Radiometer RF Box

The X_L-, K_U-, and C-band feed systems for the radiometer have been fabricated and are undergoing field evaluation tests at the antenna test range.

Structural Design and Fabrication:— The mechanical design of the radiometer box is 95 percent complete, and fabrication is 90 percent complete. Current design areas include the roof closeout and the lead ballast compartment. The rack support structure, roof closeout, overhead air plenum, painting, and tile floor installations are scheduled to be completed by 1 March. At that time, installation of cabling and electronic equipment will start. The air conditioner has been delivered, and the feed support housing is scheduled to be delivered and installed by 20 March.

c. Test Dock No. 1

Work on the architectural and engineering drawings for the test dock within the radome has been temporarily abandoned in favor of setting up a station within the Haystack storage building to permit earlier weighing and balancing operations on the radiometer box.

d. Test Dock No. 2 (Cornucopia Dock)

This outdoor facility, in addition to the radiometer-box pads and the horn-reflector pedestal, will have a trailer to temporarily house the equipment necessary for dock operation.

Mechanical components of the horn-reflector pedestal and drive system are in the process of fabrication and are scheduled for delivery at the end of March.

A program, which has been scheduled for the latter part of February at the Lincoln Laboratory antenna test range, will include RF testing of the horn reflector, and determination of an RF mechanical axis to facilitate final alignment of the horn reflector at the Haystack test dock.

Horn-reflector drive controls, position indicator controls, and electrical cabling requirements are in the process of fabrication and procurement.

2. System Interconnection

a. Control Room

The patch panel console was delivered to the site and installed during the week of 27 January 1964.

The first shipment of plug cable assemblies for the patch panel and control room junction boxes has arrived at the site and the remaining plug cable assemblies are expected by 1 April 1964. Fabrication of the receptacle plug assemblies for the patch panel and RF boxes will start upon completion of the plug cable assemblies.

Fabrication of the cable handling equipment within the control room junction boxes has been completed.

Cable routing drawings for the control room racks, describing all subsystem wiring, are approximately 80 percent complete.

b. Antenna

All antenna junction boxes have been fabricated and delivered to the site for installation by North American Aviation, Inc. (NAA).

c. Distilled Water Pipe Lines

A detailed design study has begun on the distilled water pipe lines. Items which have been resolved so far include:

A flow diagram of the manifold inside the box, including all flow and temperature interlocks

Routing of pipe lines

Redesign of some of the NAA flanges to facilitate assembly

Addition of expansion joints

Release for manufacture of the azimuth wrap manifolds

Design of the quick-disconnect at the RF box

Writing of manufacturing and performance specifications

3. Site Construction

The Construction Engineering Group at Haystack Hill continued work on secondary and special power distribution systems, designed a CO_2 fire protection system for the underfloor area of the control room, installed a temporary radome heating system, and designed the cornucopia test pad area.

a. Power Distribution

During this reporting period, the scope of the electrical power distribution system was expanded. Requirements for the distribution of 60- and 400-cps power in the control room and in test dock areas Nos. 1 and 2 were formulated and design was started.

The design and installation work on the secondary power distribution system in the control room is progressing satisfactorily.

b. CO_2 Fire Protection System

Because of the quantity of cabling to be installed in the underfloor area of the control room, it was decided that the area should be protected from fire. Since the cabling area is accessible, personnel safety was carefully considered in the design. Time-delay and manual controls will be installed in the system so that personnel in the area will have sufficient time to evacuate the crawl space before the area is flooded with CO_2. Automatic dampers will be installed in all ventilation grills located in the crawl space to prevent CO_2 from being distributed through the buildings via the air conditioning systems.

The piped distribution system is to be actuated by heat detection devices that were installed at the time of the original building construction.

In addition to the underfloor system, a hose reel station will serve the adjacent areas, supplementing the small portable extinguishers now installed.

c. Temporary Radome Heat

Shortly after the onset of winter, it became necessary to provide some form of temporary heat within the 150-foot radome so that precision antenna assembly operations could continue.

A heating system was designed that would maintain the temperature 20°F above outside ambient.

The heating system that has been installed consists of twelve externally vented, oil-fired warm air heaters with a total rated output of 2,400,000 Btu/hr. Difficulty has been experienced with the heaters because of the turbulence and increased velocity of the air about the base of the radome. With the aid of various down-draft devices, the heater operation has been maintained so that the desired results have been achieved.

d. Cornucopia Test Pad

Reinforced concrete piers to support the cornucopia horn, RF hut, and a pad for a mobile laboratory have been designed, procured and are presently being constructed. A cable duct that will contain power and signal cables is also included in this program.

4. Antenna Structural Analysis

The computer program (IBM's FRAN – frame analysis) for analysis of the deflectional interaction of the antenna backup structure with the reflector surface is still in the debugging stage. This program is now handling approximately 5000 unknowns, whereas in the STAIR program slightly over 1000 unknowns were handled. Machine difficulty, as well as small input data errors, delayed the first complete computer run until this writing. As the quarter ended, the FRAN results were being evaluated. Acceptable results are being sought for comparison with the results of full-scale antenna load-deflection tests scheduled for the next quarter.

B. North American Aviation Activity (Antenna System)

Detailed monitoring of all phases of the Air Force and Lincoln Laboratory sponsored contracts is continuing. Activity is concentrated on-site and is in the final stages of primary mechanical assembly.

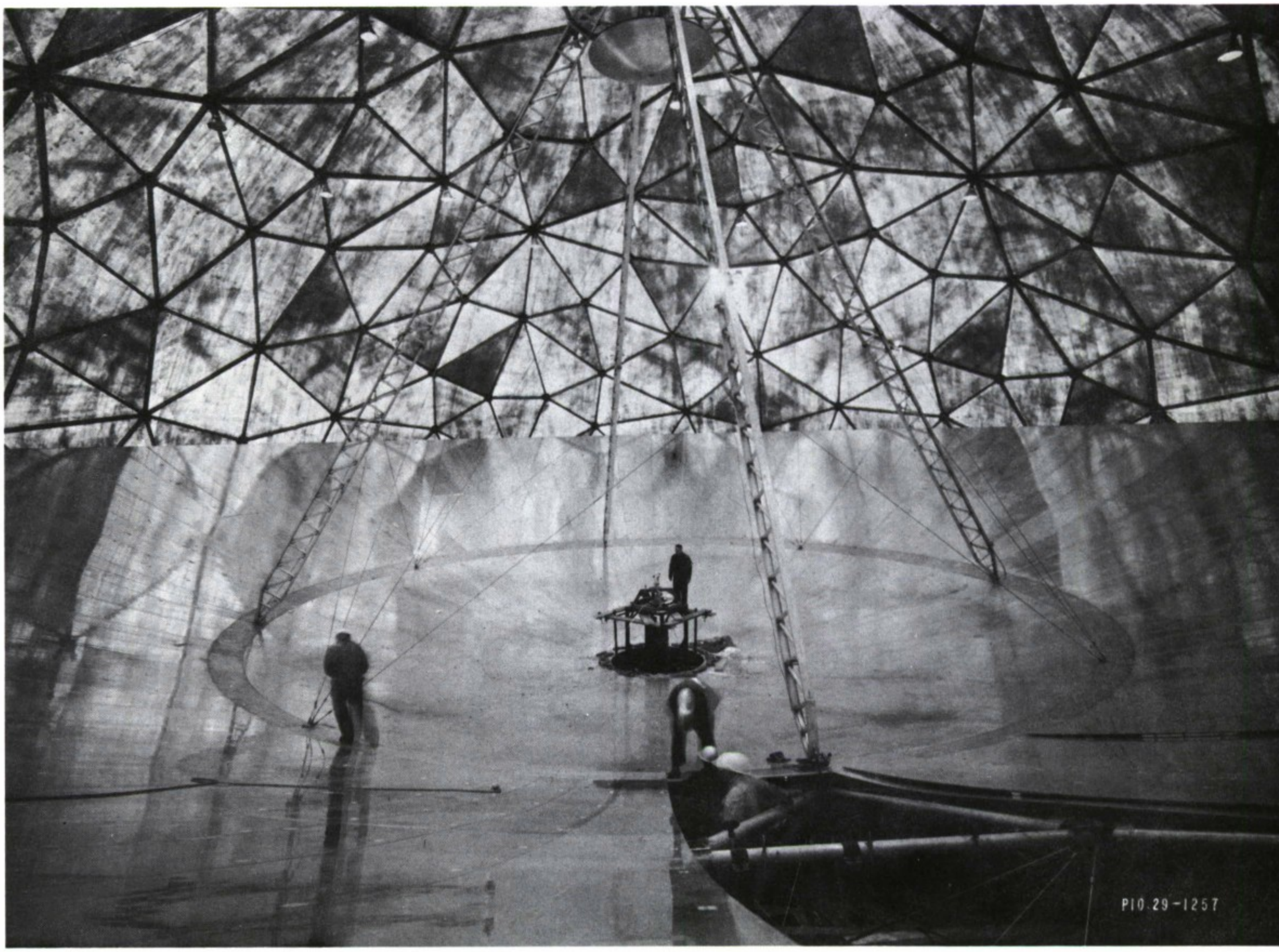

Fig. 76-1. View of reflector showing present ossembly progress.

1. Engineering and Design

a. Antenna

Engineering and design activity has now shifted in direct support of on-site installation, alignment, and rigging operations. Detailed planning of subsystem tests is under way. The first on-site test will be that of reflector deflection to demonstrate the effect of the reflector honeycomb surface.

b. Angle Data System

The digital data system has been delivered to the site by the Electronic Systems Division of the Telecomputing Corporation.

c. Antenna Interconnection System

Design activity in this area has been completed, with engineering effort presently being directed toward monitoring on-site installation.

2. Manufacturing

All antenna hardware except the pendulum ballast has been shipped from NAA, Columbus, Ohio. This does not include spare parts.

3. On-Site Erection

a. Antenna Interconnection System

All bracketry above the azimuth wrap has been installed. Junction boxes at the upper two levels have been installed and junction boxes in the concrete tower are being installed. Cable installation will begin early in the next quarter. The Laboratory will supply the antenna lines required for dry air and distilled water.

b. Antenna Reflector System

The reflector backup structure has been checked for elevation and radius of the five rings, along with the tension in all intra-ring and inter-ring tension rods. Although the tolerances were exceeded in both optical and tension checks, the variations were acceptable since the structural integrity of the reflector and the adjustment range of the panel standoff studs were not seriously affected. All 32 inner panels, including cables, expanders, and panel rigging aids, were installed. A cursory survey of targets was made after which the targets over rings 1 and 2 were roughly aligned, within ±0.030 inch of the theoretical parabola, with the optical probe.

Installation of the secondary reflector and support assembly followed the rough rigging of the inner panels on the primary reflector. Alignment of the hyperbolic secondary reflector axis with respect to the focal axis of the parabola as defined by the primary scope was accomplished. Initial installation of 62 out of 64 outboard panels was also accomplished at the close of this reporting period. Figure 76-1 shows the optical probe, inner panels, secondary reflector with its support structure, and the installation of outer panels in progress.